

Large-scale Array of Small High-Q Microdisk Resonators for On-chip Spectral Analysis

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Abstract: We demonstrate on-chip, large-scale arrays of small high-Q microdisk resonators, suitable for both in-plane coupling and out-of-plane (imaging) spectral analysis devices with high resolution (linewidth $< 50\text{pm}$ to 0.5nm), and large FSR ($> 50\text{nm}$).

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Recently, microresonator-based filters have been actively pursued in silicon photonics platform for a variety of applications and functionalities [1,2]. In emerging applications such as lab-on-a-chip sensing, where there is a need for chip-scale devices to perform spectral analysis, a major challenge is achieving ultra-high spectral resolution ($< 0.5\text{nm}$) in large-scale arrays. In this work, we propose and demonstrate such a large-scale array of small, high-Q microdisk resonators for the on-chip spectral analysis. The compactness and large free-spectral-range (FSR) of the filter are two important figures of merit that are improved by shrinking the resonator size. We demonstrate both in-plane coupling and out-of-plane (imaging) spectral analysis using devices with high resolution (linewidth $< 50\text{pm}$ to 0.5nm), and large FSR (free-spectral range $> 50\text{nm}$).

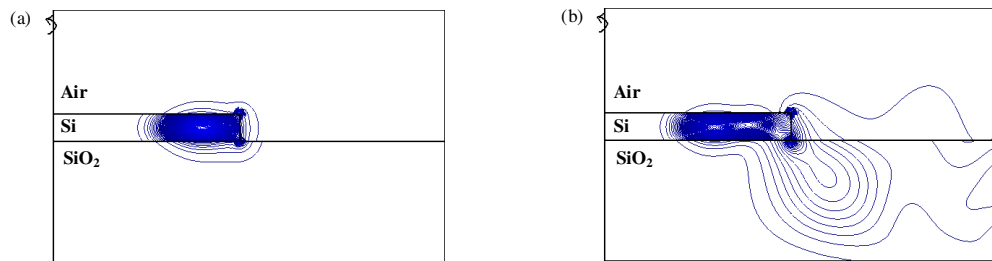


Figure 1: The cross sections of the simulated electric energy distributions of (a) the 1st and (b) the 2nd radial order mode of a silicon microdisk resonator with a radius of $1.4\text{ }\mu\text{m}$ and a thickness of 200 nm . The resonance wavelengths of the modes are around 1550 nm , and the corresponding azimuth mode numbers are 11 and 8 for the 1st mode and the 2nd mode, respectively. The polarization considered is TE (electric field is predominantly in the plane of the disk).

A key feature of such small microdisk resonators is that by adjusting the radius and the thickness of the microdisk, the higher-order radial modes are strongly suppressed because of their radiative leakage. The higher-order modes can be suppressed further by etching a hole at the center of the microdisk. This enables a pure

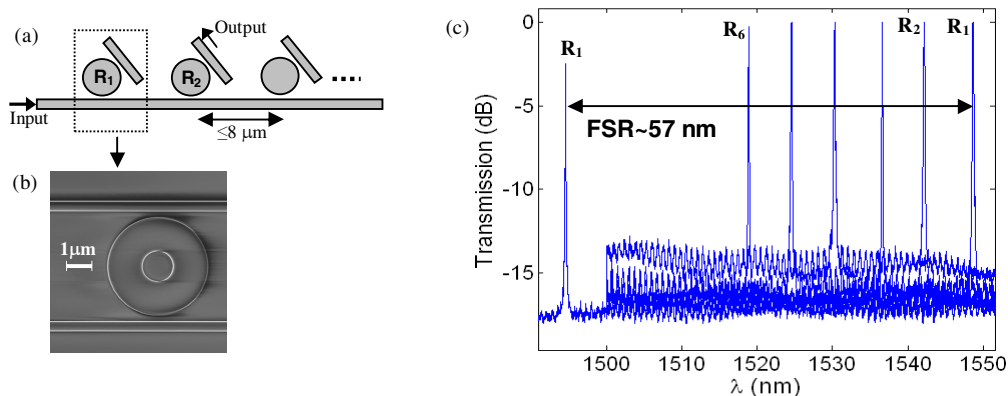


Figure 2: (a) A schematic drawing of the resonator array for in-plane spectral analysis. (b) The SEM image of one of the fabricated resonators in the array which has a radius of $2\text{ }\mu\text{m}$. The structure is covered with an oxide cladding. (c) Measured transmission of the drop ports of an array of 6 resonators coupled to a bus waveguide. The FSR is $\sim 57\text{ nm}$ and the spectral linewidth was designed to be in the range of 50 to 100 pm .

single-mode operation for a very wide wavelength range while preserving the high-Q of the first radial order mode. This is clearly seen in the simulated mode energy distributions for the first and second radial order modes in small microdisk resonators with a radius of 1.4 μm , shown in Fig 1. While coarse tuning of the resonance wavelength is achieved by adjusting the outer radius of the disk, the fine tuning of the resonance (<10 pm wavelength accuracy) is achieved by changing the size of the perforated hole which is far from the peak of the mode energy. Figure 2(a) shows an in-plane coupling of 6 add-drop resonators coupled to a single bus waveguide. The schematic of the device is shown in Fig. 2(b). The linewidth $\sim 50\text{pm}$ to 100pm was obtained for all the peaks and the higher radial order modes were suppressed. An intrinsic $Q \approx 10^5$ was observed for the 1st order mode. Integrating the structures with metal heaters enables the dynamic tuning of the resonator array. Figure 3 shows an out-of-plane (imaging) of 32 resonators coupled to a single-bus waveguide. Each row

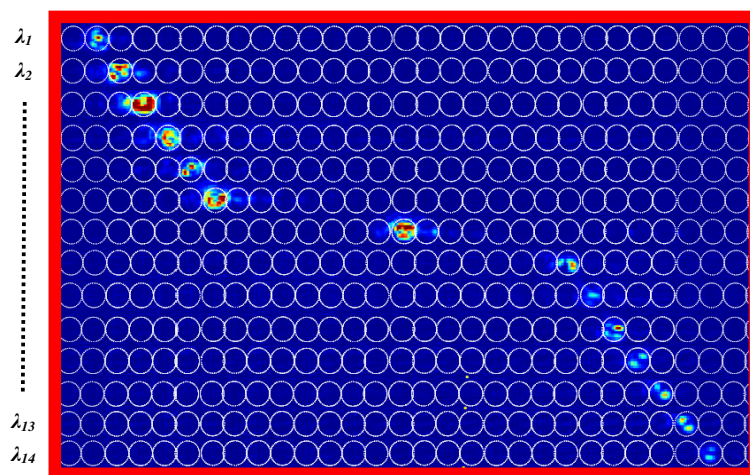


Figure 3: Top-view imaging of an array of 32 resonators coupled to a single bus waveguide. Each row corresponds to the scattering image for input wavelength close to the resonance wavelength of each resonator.

corresponds to the image for a separate input wavelength. Clear differentiation of spatial patterns for the resonance wavelengths, with low crosstalk from adjacent resonators is observed, suitable for on-chip spectral analysis. Moreover, by using a large-scale array of such microdisk resonators, we can cover the entire FSR and efficiently detect spectral signatures in the input at any wavelength within the FSR. More results on the performance of the large-scale resonator array will be presented in the conference.

References

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